



**Federal Aviation  
Administration**

# Rotorcraft Damage Tolerance R&D

## FAA Rotorcraft Structural Integrity and Safety

Presented to: Rotorcraft Community

By: Dy Le – FAA Rotorcraft Program manager

Date: March 21, 2006



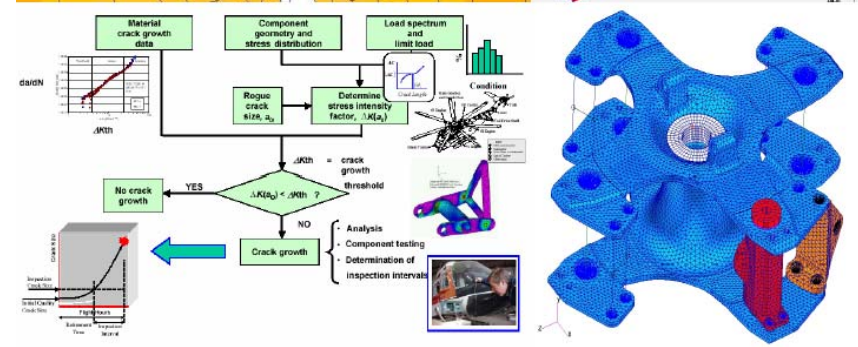
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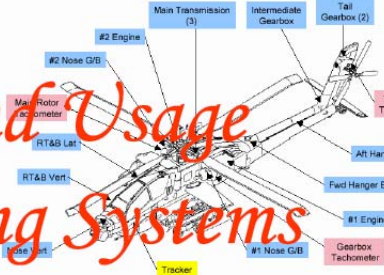
# Agenda - Presentation Outline

- ➔ FAA Rotorcraft Structures Research Overview
- ➔ RCDDT R&D History and Status
  - ➔ Joint RCDDT Efforts
  - ➔ RCDDT Accomplishment
  - ➔ RCDDT Technology Readiness Level Status
- ➔ Overview of the Development of RCDDT R&D Strategic Plan and Roadmap
- ➔ FAA RCDDT R&D Roadmap
- ➔ FAA RCDDT & HUMS BAAs Status - Q&A

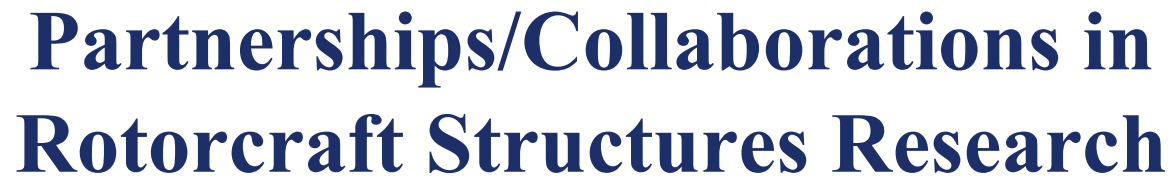
# Rotorcraft Structural Integrity and Safety



*Health and Usage Monitoring Systems (HUMS)*







**NASA Ames Res. Ctr.**  
**Moffett Field, CA**




**William J. Hughes  
Technical Center  
Atlantic City Int'l Airport, NJ**

**Civil Aviation  
Authority  
(CAA)**



**Rotorcraft Directorate**  
**Fort Worth, TX**

**Center for  
Rotorcraft  
Innovation**



**FAA  
of Excellence  
Academia**

**Sikorsky  
Stratford, CT**



**Boeing**  
**Philadelphia, PA**  
**Naval Air Warfare Center,**  
**Aircraft Division**  
**Patuxent River, MD**



**NASA Langley Res. Ctr.,  
Hampton, VA**

—Army Vehicle Tech. Ctr., ARL  
Hampton, VA

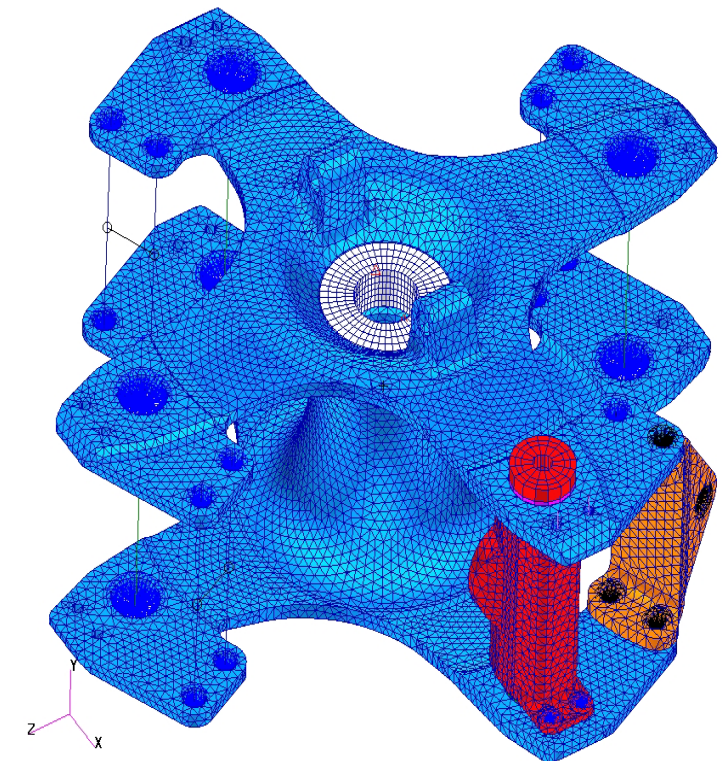
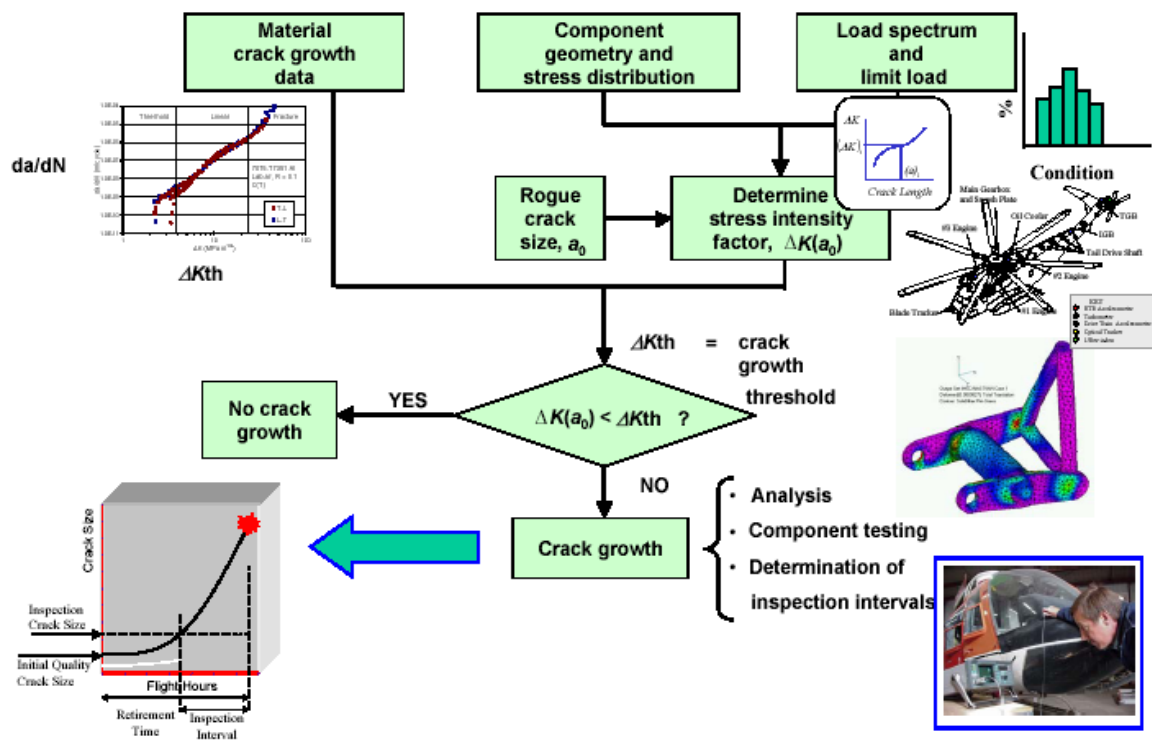
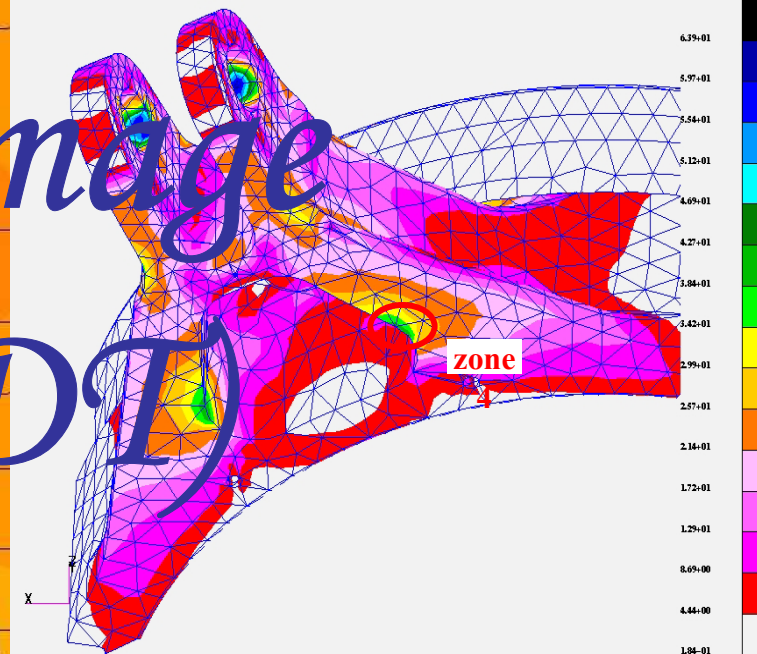


**Bell Helicopter** **TEXTRON** *Bell*  
A Subsidiary of Textron Inc. *Fort Worth, TX*

**NASA Johnson  
Space Center  
Houston, TX**

**A joint rotorcraft program with industry, academia, DoD, and other government research agencies to develop and validate mutually agreed-upon technologies that will address rotorcraft structures design and certification issues.**

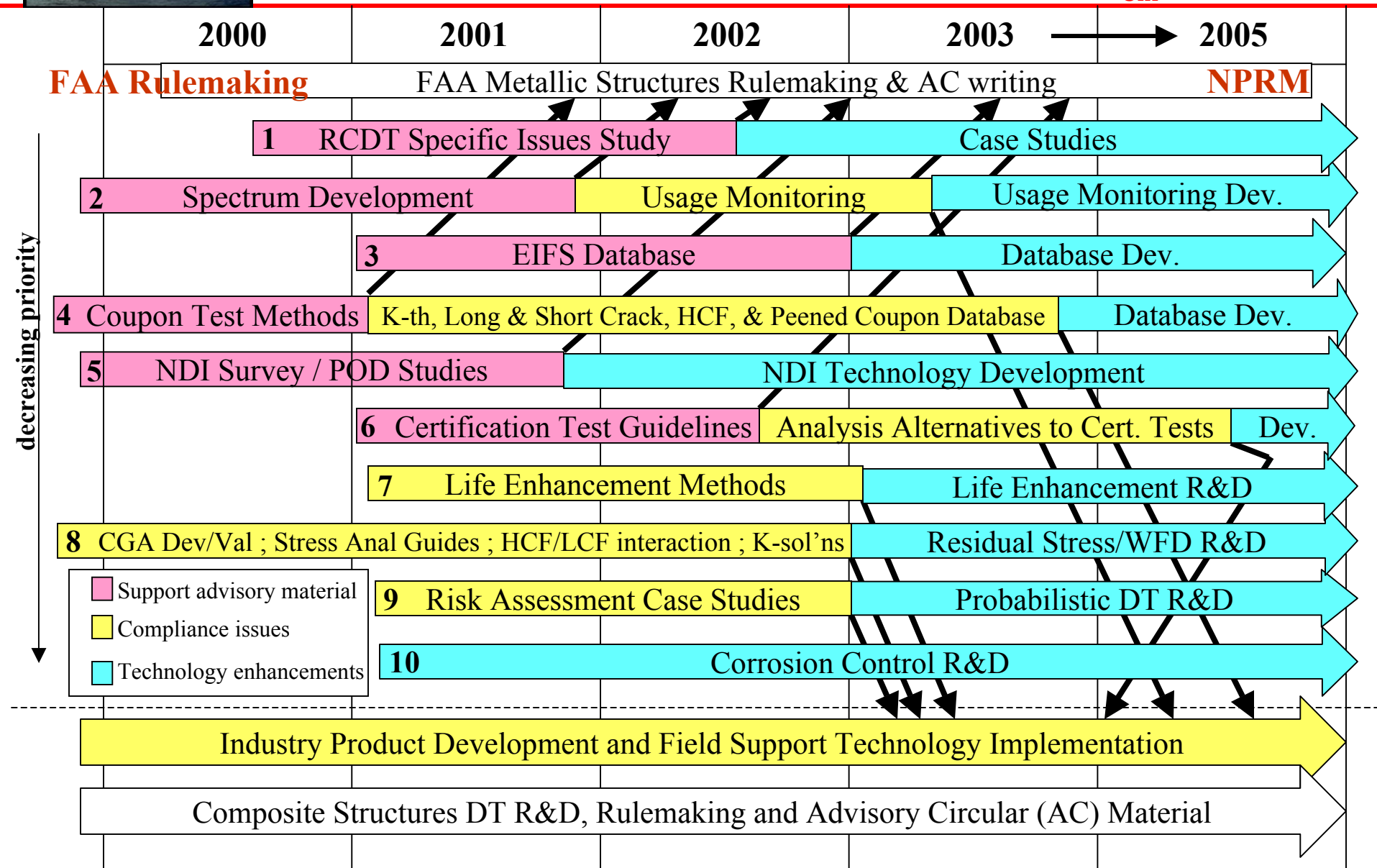
# Rotorcraft Damage Tolerance (RCDT)



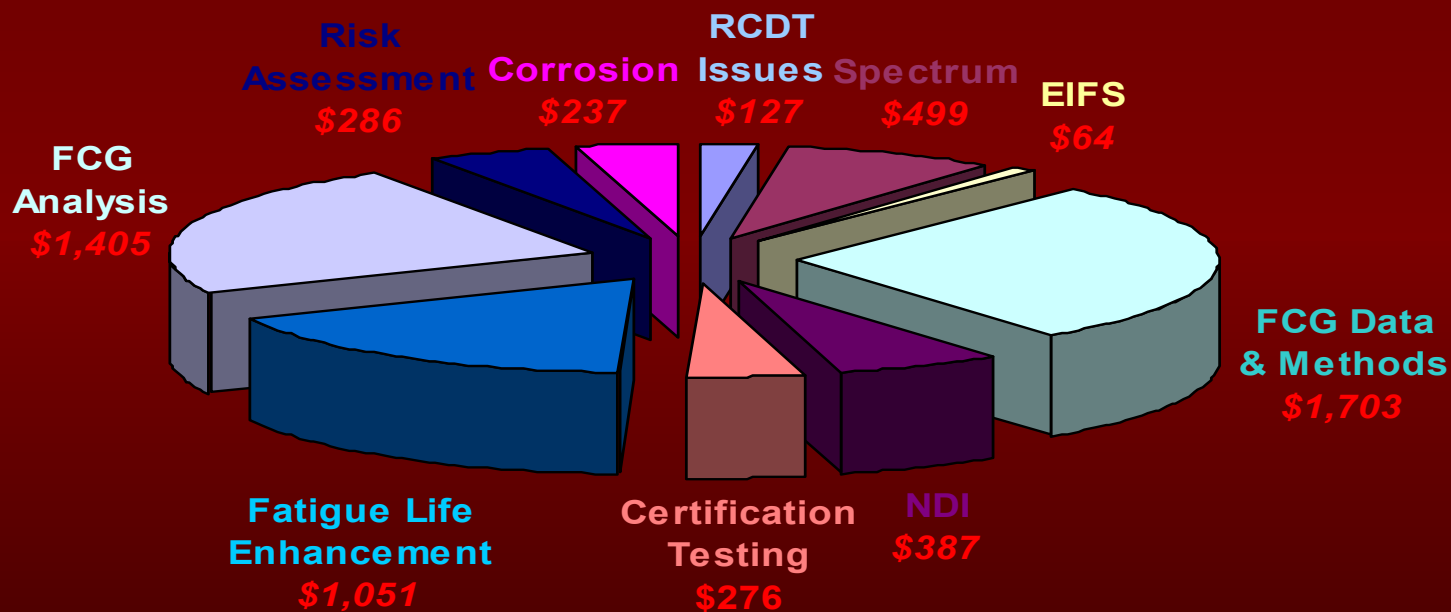




# RCDT R&D Roadmap



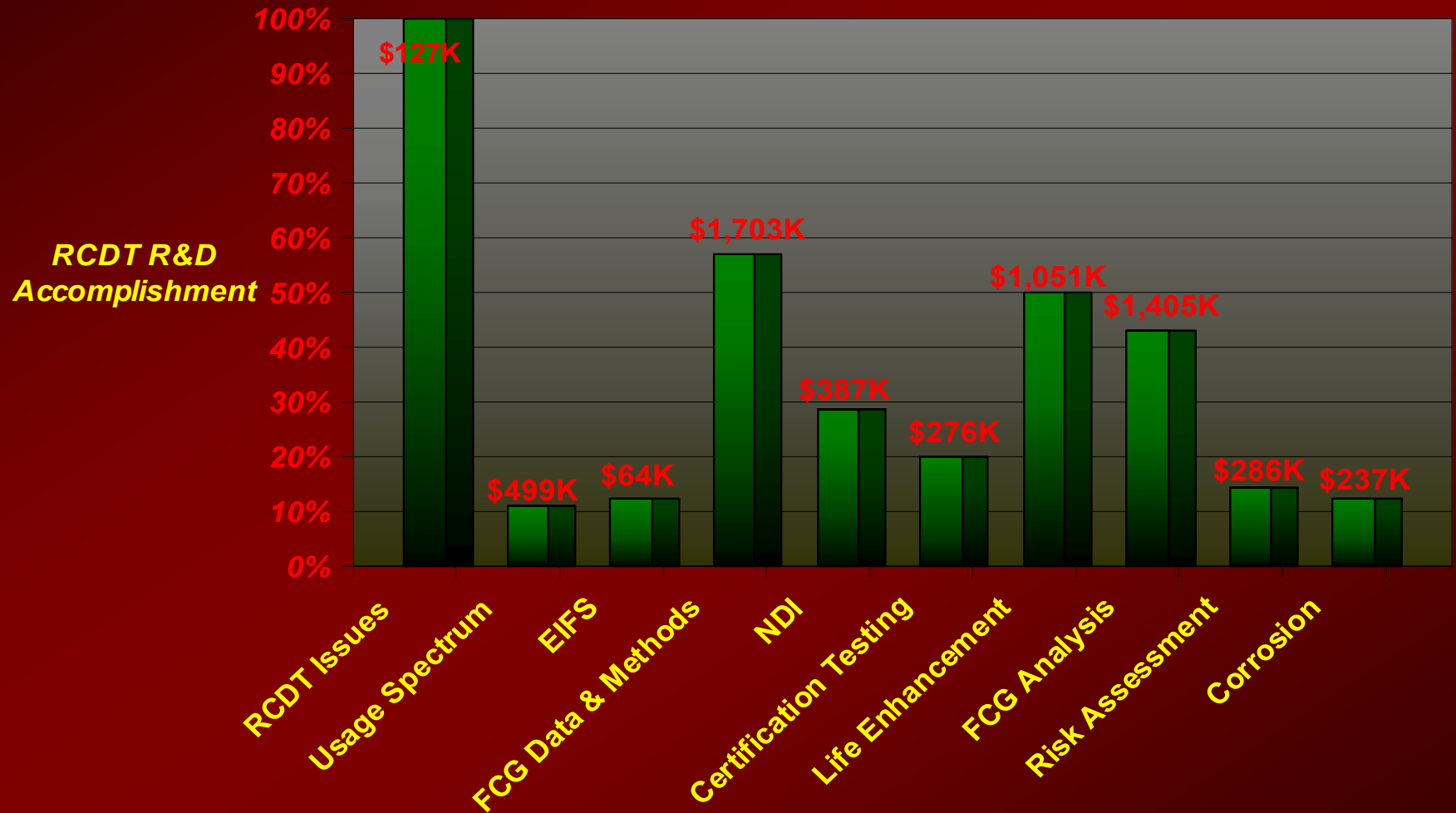
# FAA RCDT Phase I R&D Funding (\$K)



FY00 - FY05 (\$6M)



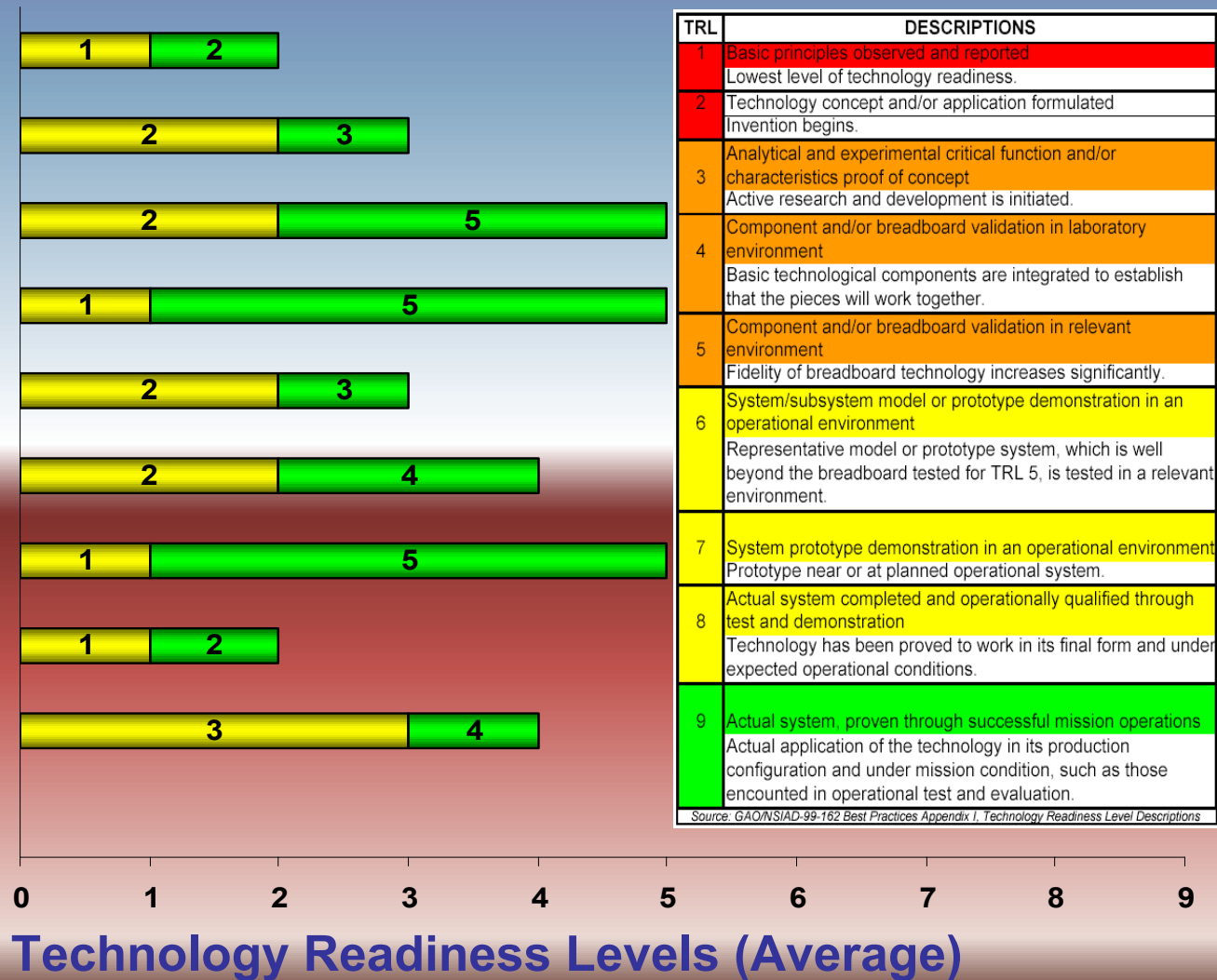
# FAA RCDT Research Status and Accomplishment FY00 - FY05 (\$6M)



# RCDT TRL Status (FY00 - FY05)

■ Original TRL ■ Currently Achieved TRL

Corrosion  
Risk Assessment  
FCG Analysis  
Life Enhancement  
Certification Testing  
NDI  
FCG Data & Methods  
EIFS  
Usage Spectrum  
RCDT Issues



# RCDT R&D STRATEGIC PLAN

## DEVELOPMENT INITIATIVES

- ✈ Rotorcraft Community RCDT and Fracture Mechanics R&D Perspectives
  - ✈ OEM's, Academia, Government
- ✈ FAA's RCDT R&D Perspectives
  - ✈ FAA-Rotorcraft Community combined assessment of current state of RCDT technologies
  - ✈ FAA's process to identify and prioritize RCDT R&D needs

# FAA RCDT R&D Plan Development

- RCDT technology assessment and gap analysis
  - RCDT technology matrices
  - TRL criteria
- Identified R&D needs
  - FAA regulation support criteria
- Development of RCDT R&D Roadmap
  - FAA R&D prioritization criteria
- Development of RCDT R&D strategic plan
  - Output requirements & performance metrics
  - exit criteria/strategy
  - ROM



# RCDT Technology Matrices

- ➔ Usage and Load Spectrum
- ➔ Initial Crack State
- ➔ Material Fatigue Crack Growth (FCG) Data
- ➔ Fracture Mechanics (FM) and FCG Analyses
- ➔ Risk Assessment – Probabilistics
- ➔ Non-Destructive Inspections and Evaluations
- ➔ RCDT Demonstration and Compliance
- ➔ RCDT Documentation
- ➔ Regulatory Implementation and Technology Transfer

# FEDERAL AVIATION ADMINISTRATION

## Rotorcraft Damage Tolerance (RCDT) Gap Analysis

**IDENTIFIED**

### Technology Assessment

### Current State of Technology

### Regulation Support Criteria

Current

Required

Years

Technology

Technology

Certification

Applicable to

Is this

TRL

TRL

To Fully

Risk

Gaps

Readiness

RCDT Reg?

an R&D task?

(1 to 9)

(1 or 9)

Operational

(0, 1, 2, or 3)

Ready = 0

Yes = 0

Yes = 0

(or to TRL 9)

Not Ready=1

No = 1

No = 1

**TECHNOLOGY  
NEEDS**

### OVERALL RCDT TECHNOLOGY STATUS

### Component Stress Distribution

### Finite Element Methods and Codes

### Usage and Load Spectrum

### Usage Data Collection

### Load Spectrum

### RHL

### Initial Crack Size State

### Determination of Equivalent Initial Flaw

### Establishment of RC Damage Database

### Update FCG models to make EIFS be independent load levels

### Assessment of Reliability and Maintainability (R&M) FRACAS and RCDT damage databases

### Determination of Normal Quality and Rogue EIFS Distribution

### Characterization of small initial damage states

### development and application of EIFS to RCDT design and management for manufacturing and in-service damage threats

**4 7 3 2 3 0 98% 96%**

**4 7 3 2 3 0% 100% 100%**

**4 7 3 2.0 3 0% 100% 100%**

5 7 3 2 2 1 0 0

3 7 3 2 4 1 0 0

**4 9 3 2 4 0% 100% 100%**

**5 8 3 2 3 0% 100% 100%**

4 9 3 2 5 1 0 0

7 9 3 1 2 1 0 0

5 7 2 2 2 1 0 0

**4 9 5 2 5 0% 100% 100%**

4 9 5 2 5 1 0 0

4 9 5 2 5 1 0 0

**4 9 2 2 5 0% 100% 100%**

4 9 2 2 5 1 0 0

**3 6 3 2 3 0 100% 89%**

**3 6 3 2 3 0% 100% 89%**

2 6 5 3 4 1 0 0

4 6 2 2 2 1 0 0

4 6 2 2 2 1 0 1

2 6 5 3 4 1 0 0

2 8 3 3 6 1 0 0

2 6 2 3 4 1 0 0

FEA Enhancement

FEA & FM Interface

Establishment of Typical  
Spectrum Using HUMS

Usage Monitoring

FCG & Load Sensitivity

Strain Survey

Using HUMS

Repeated Heavy Lift

Damage Database

FCG Models

No

Quality and Rogue EIFS  
Distribution

Characterization of small  
initial damage states

EIFS Development  
Guidelines

# RCDT ASSESSMENT AND GAP ANALYSIS



# GAO Technology Readiness Levels

Normally at TRL 9, but can be lower

Years to bring technology to required TRL

Technology Maturation Risk

(Current – Required) TRL

Certified?

Technology Maturation Risk (TMR)

TRL	Risk	TMR
0	High	3
1	High	3
2	High	3
3	Medium	2
4	Medium	2
5	Medium	2
6	Low	1
7	Low	1
8	Low	1
9	No Risk	0

## Rotorcraft Damage Tolerance (RCDT) Gap Analysis

IDENTIFIED

### Technology Assessment

### Current State of Technology

### Regulation Support Criteria

Current TRL (1 to 9)	Required TRL (1 or 9)	Years To Fully Operational (or to TRL 9)	Technology Risk (0, 1, 2, or 3)	Technology Gaps	Certification Readiness Ready = 0 Not Ready=1	Applicable to RCDT Reg? Yes = 0 No = 1	Is this an R&D task? Yes = 0 No = 1
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TECHNOLOGY  
NEEDS

FAR 27.571 & 29.571

Must be research in nature

Selected for  
prioritization





# FEDERAL AVIATION ADMINISTRATION

## Rotorcraft Damage Tolerance (RCDT) Gap Analysis

**IDENTIFIED**

Technology Assessment			Current State of Technology			Regulation Support Criteria		
Current TRL (1 to 9)	Required TRL (1 or 9)	Years To Fully Operational (or to TRL 9)	Technology Risk (0, 1, 2, or 3)	Technology Gaps	Certification Readiness Ready = 0 Not Ready=1	Applicable to RCDT Reg? Yes = 0 No = 1	Is this an R&D task? Yes = 0 No = 1	

**TECHNOLOGY  
NEEDS**

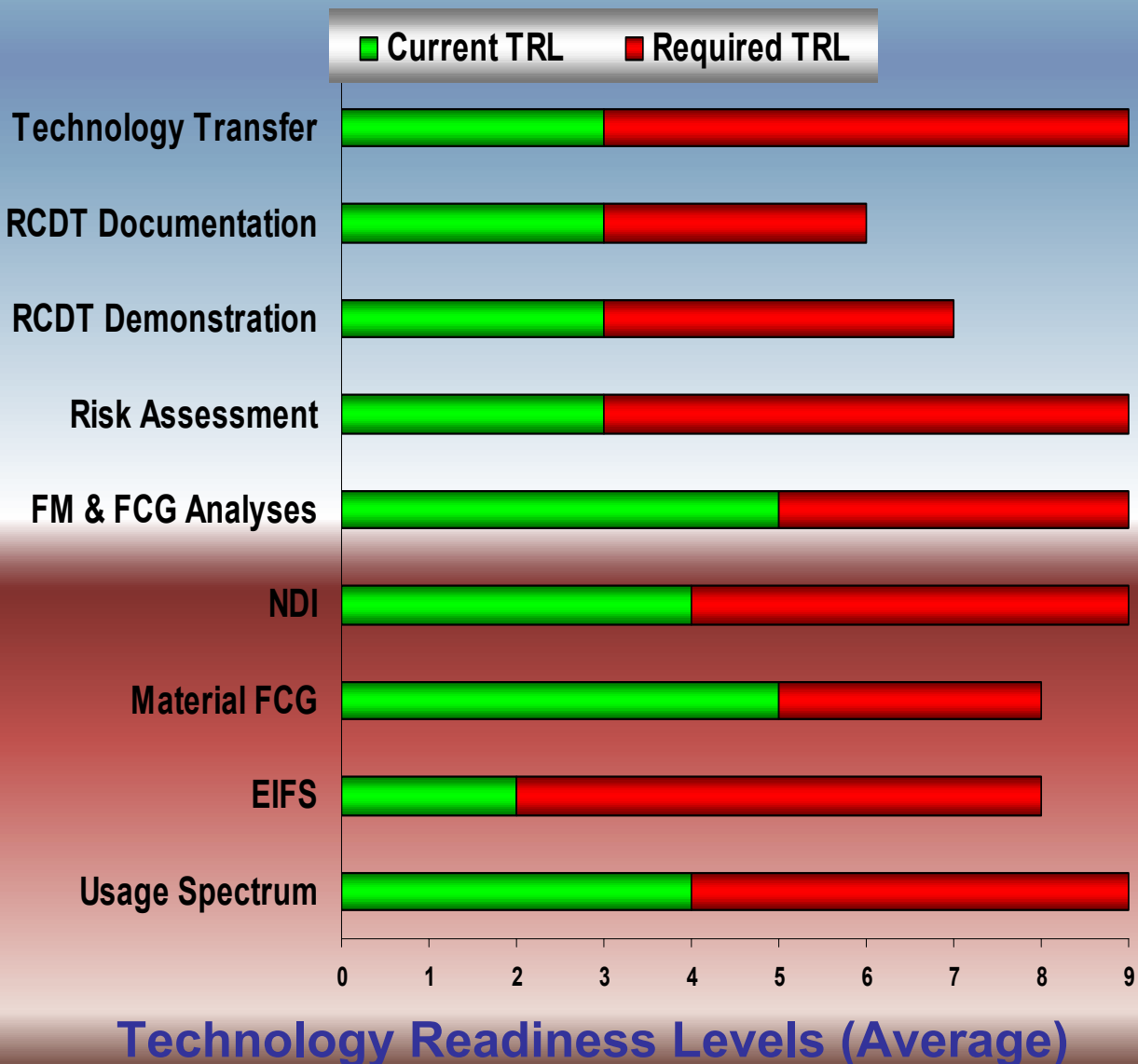
### OVERALL RCDT TECHNOLOGY STATUS

#### Component Stress Distribution

#### Finite Element Methods and Codes

	Enhancement of FEA complex geometry, non-linear stress field	5	7	3	2	3	0	98%	96%	FEA Enhancement
	and fracture mechanics codes (integration)	3	7	3	2	4	1	0	0	FEA & FM Interface
Usage and Load Spectrum		4	9	3	2	4	0	100%	100%	
Usage Data Collection		5	8	3	2	3	0	100%	100%	
	Establishment of Typical Spectrum Using HUMS	4	9	3	2	5	1	0	0	Establishment of Typical Spectrum Using HUMS
	Usage monitoring using HUMS	7	9	3	1	2	1	0	0	Usage Monitoring
	Sensitivity of FCG to usage/load spectra variations	5	7	2	2	2	1	0	0	FCG & Load Sensitivity
Load Spectrum		4	9	5	2	5	0	100%	100%	
	Heavy lift components strain survey	4	9	5	2	5	1	0	0	Strain Survey
	Direct Load Measuring Using HUMS	4	9	5	2	5	1	0	0	Using HUMS
RHL		4	9	2	2	5	0	100%	100%	
	RC Fatigue Life	4	9	2	2	5	1	0	0	Repeated Heavy Lift
Initial Crack Size State		3	6	3	2	3	0	100%	89%	
Determination of Equivalent Initial Flaw		3	6	3	2	3	0	100%	89%	
	Establishment of RC Damage Database	2	6	5	3	4	1	0	0	Damage Database
	Update FCG models to make EIFS be independent load levels	4	6	2	2	2	1	0	0	FCG Models
	Assessment of Reliability and Maintainability (R&M) FRACAS and RCDT damage databases	4	6	2	2	2	1	0	1	No
	Determination of Normal Quality and Rogue EIFS Distribution	2	6	5	3	4	1	0	0	Quality and Rogue EIFS Distribution
	Characterization of small initial damage states	2	8	3	3	6	1	0	0	Characterization of small initial damage states
	development and application of EIFS to RCDT design and management for manufacturing and in-service damage threats	2	6	2	3	4	1	0	0	EIFS Development Guidelines

# RCDT Technology Readiness Level Gaps



TRL	DESCRIPTIONS
1	Basic principles observed and reported Lowest level of technology readiness.
2	Technology concept and/or application formulated Invention begins.
3	Analytical and experimental critical function and/or characteristics proof of concept Active research and development is initiated.
4	Component and/or breadboard validation in laboratory environment Basic technological components are integrated to establish that the pieces will work together.
5	Component and/or breadboard validation in relevant environment Fidelity of breadboard technology increases significantly.
6	System/subsystem model or prototype demonstration in an operational environment Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment.
7	System prototype demonstration in an operational environment Prototype near or at planned operational system.
8	Actual system completed and operationally qualified through test and demonstration Technology has been proved to work in its final form and under expected operational conditions.
9	Actual system, proven through successful mission operations Actual application of the technology in its production configuration and under mission condition, such as those encountered in operational test and evaluation.

Source: GAO/NSIAD-99-162 Best Practices Appendix I, Technology Readiness Level Descriptions

# FAA PRIORITIZATION PROCESS









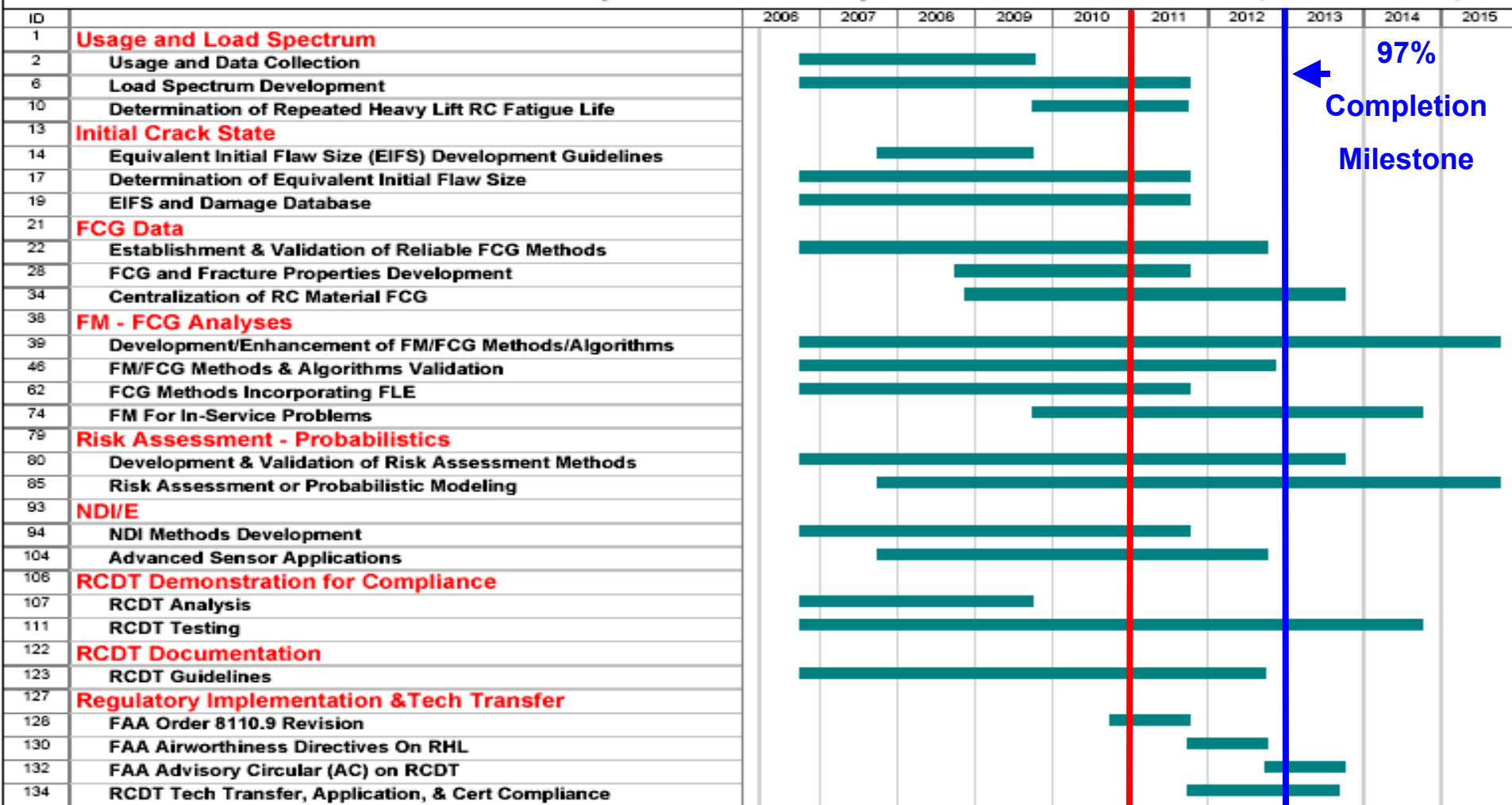


# FAA RCDDT R&D ROADMAP

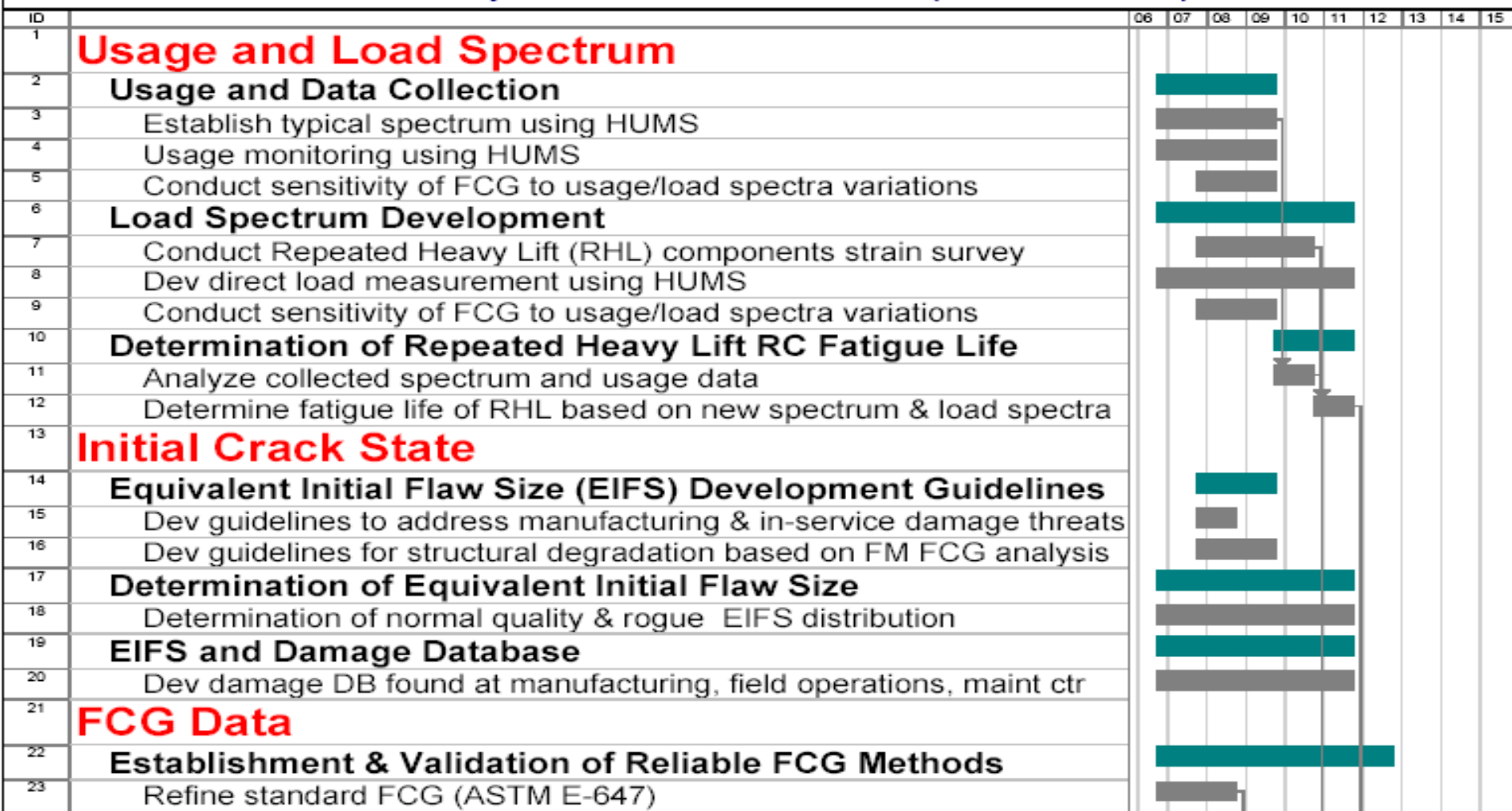


# RCDT R&D Roadmap

## DRAFT-RCDT Research & Development Roadmap for Metallic Materials-(10-Year Plan)



# **DRAFT - Rotorcraft Damage Tolerance (RCDT) Research and Development Roadmap for Metallic Materials (10-Year Plan)**



Airport and Aircraft Safety Research & Development Division  
FAA William J. Hughes Technical Center

Task

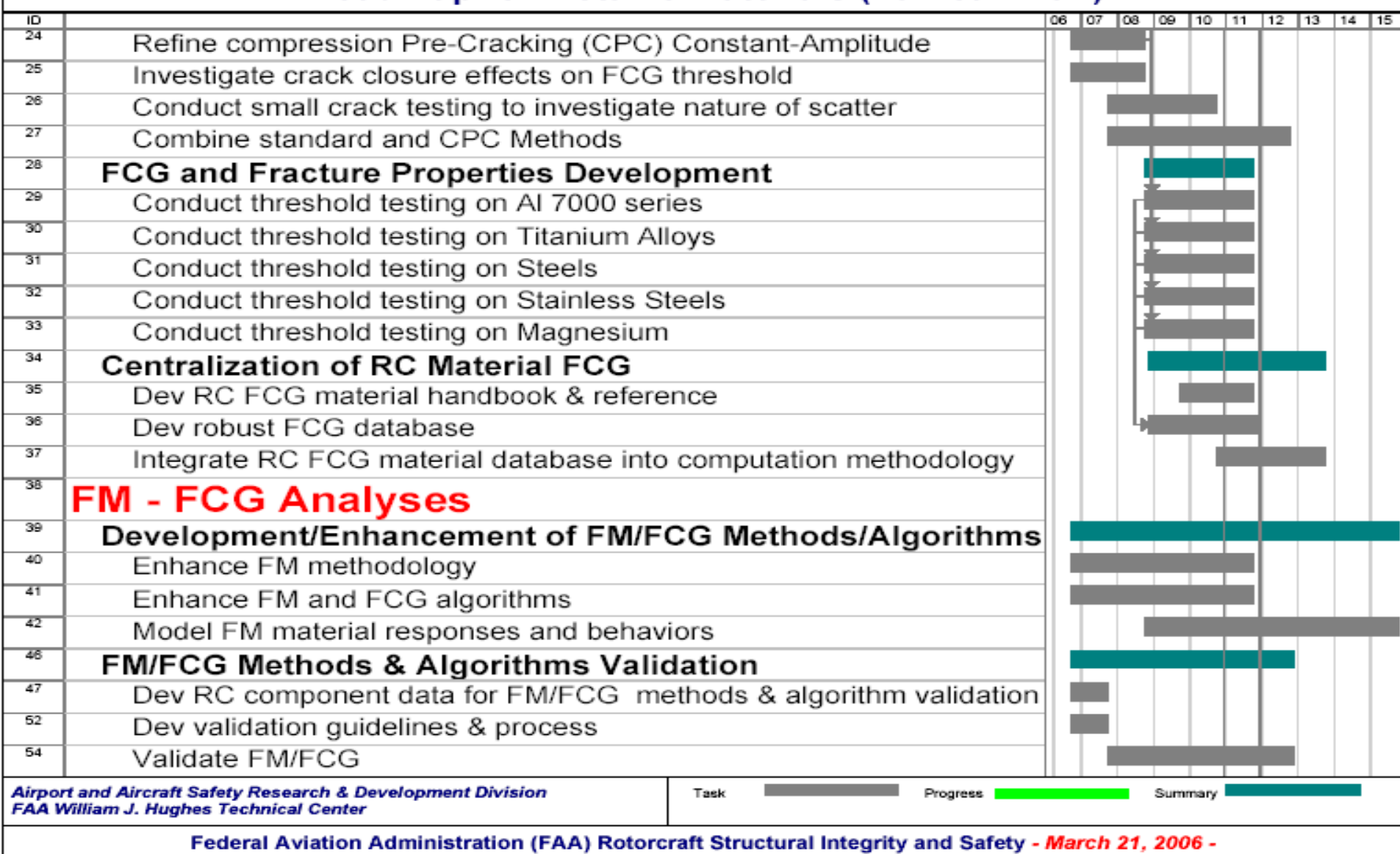
Progress

Summary

Federal Aviation Administration (FAA) Rotorcraft Structural Integrity and Safety - March 21, 2006 -

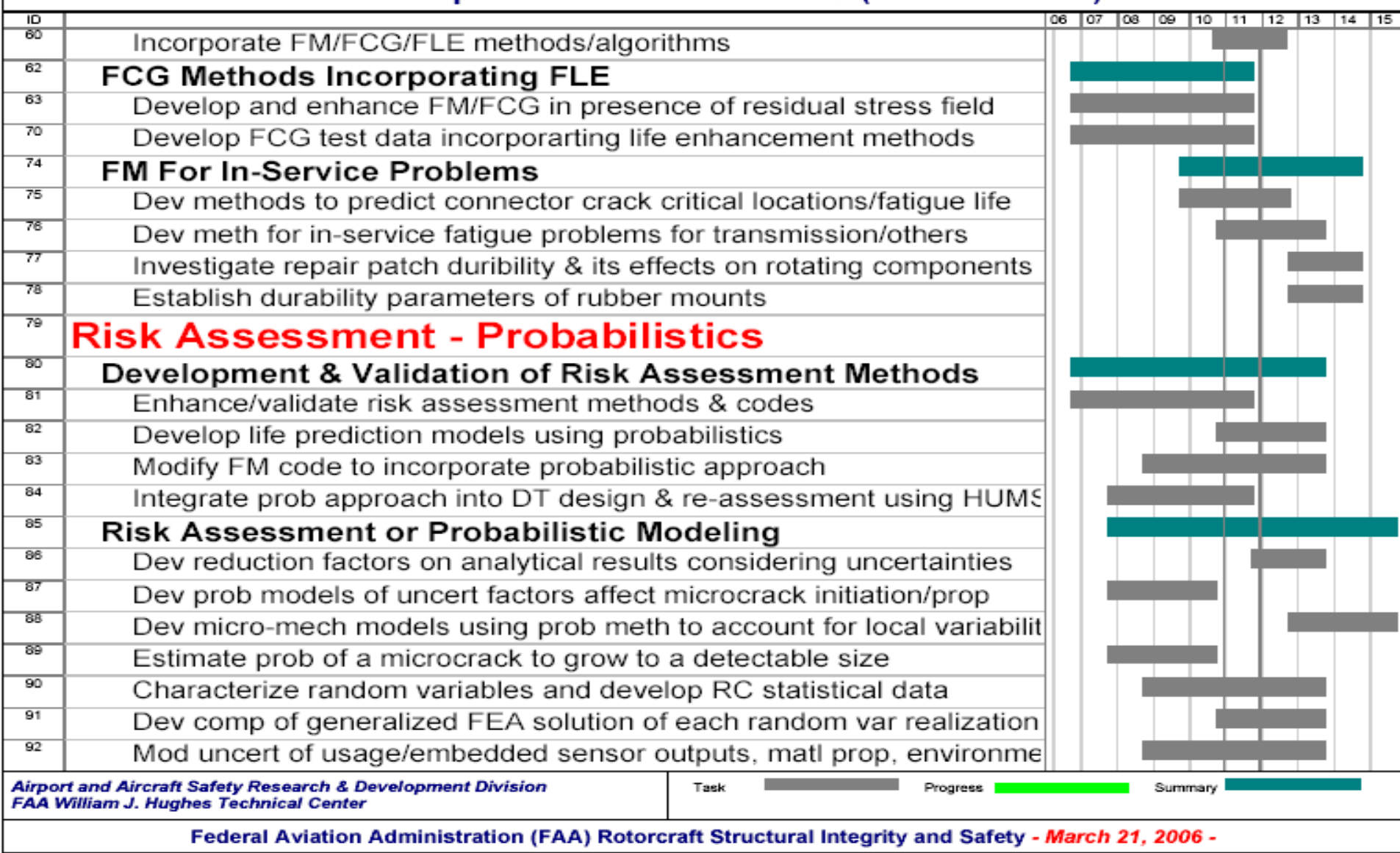


# **DRAFT - Rotorcraft Damage Tolerance (RCDT) Research and Development Roadmap for Metallic Materials (10-Year Plan)**





# **DRAFT - Rotorcraft Damage Tolerance (RCDT) Research and Development Roadmap for Metallic Materials (10-Year Plan)**





# **DRAFT - Rotorcraft Damage Tolerance (RCDT) Research and Development Roadmap for Metallic Materials (10-Year Plan)**

ID		06	07	08	09	10	11	12	13	14	15
93	<b>NDI/E</b>										
94	<b>NDI Methods Development</b>										
95	NDI/E tools										
97	NDI/E methodologies										
102	NDI/E manual & guidelines										
104	<b>Advanced Sensor Applications</b>										
105	Implement advanced sensor tech for crack initiation & propagation										
106	<b>RCDT Demonstration for Compliance</b>										
107	<b>RCDT Analysis</b>										
108	ID RC comp unique char, needs, requirements to code developers										
109	Conduct DT design/fatigue analysis on selected airframe structures										
110	Conduct DT design/fatigue analysis on selected dynamic components										
111	<b>RCDT Testing</b>										
112	Conduct component testing										
117	Conduct full-scaled RC component testing										
122	<b>RCDT Documentation</b>										
123	<b>RCDT Guidelines</b>										
124	Dev guidlelines for DT design, cert, & management of RC component:										
125	Dev design meth for structures using flaw size smaller than inspectabl										
126	Dev RC DT application procedure for DT design, cert, & management										
127											
128											
129											

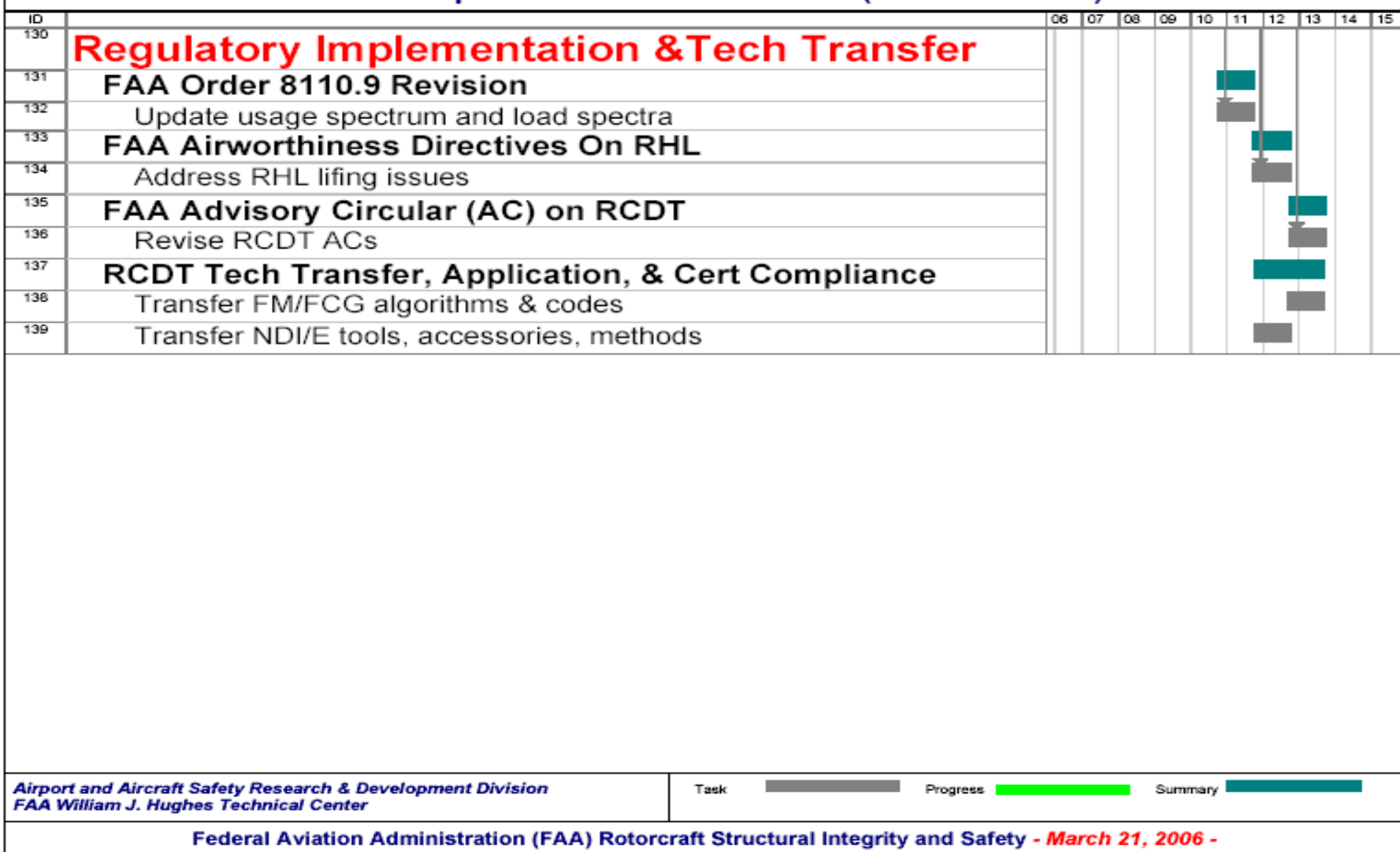
**Airport and Aircraft Safety Research & Development Division**  
**FAA William J. Hughes Technical Center**

Task  Progress  Summary 

**Federal Aviation Administration (FAA) Rotorcraft Structural Integrity and Safety - March 21, 2006 -**



# **DRAFT** - Rotorcraft Damage Tolerance (RCDT) Research and Development Roadmap for Metallic Materials (10-Year Plan)



# FAA RCDT R&D 10-Year ROM (\$K)

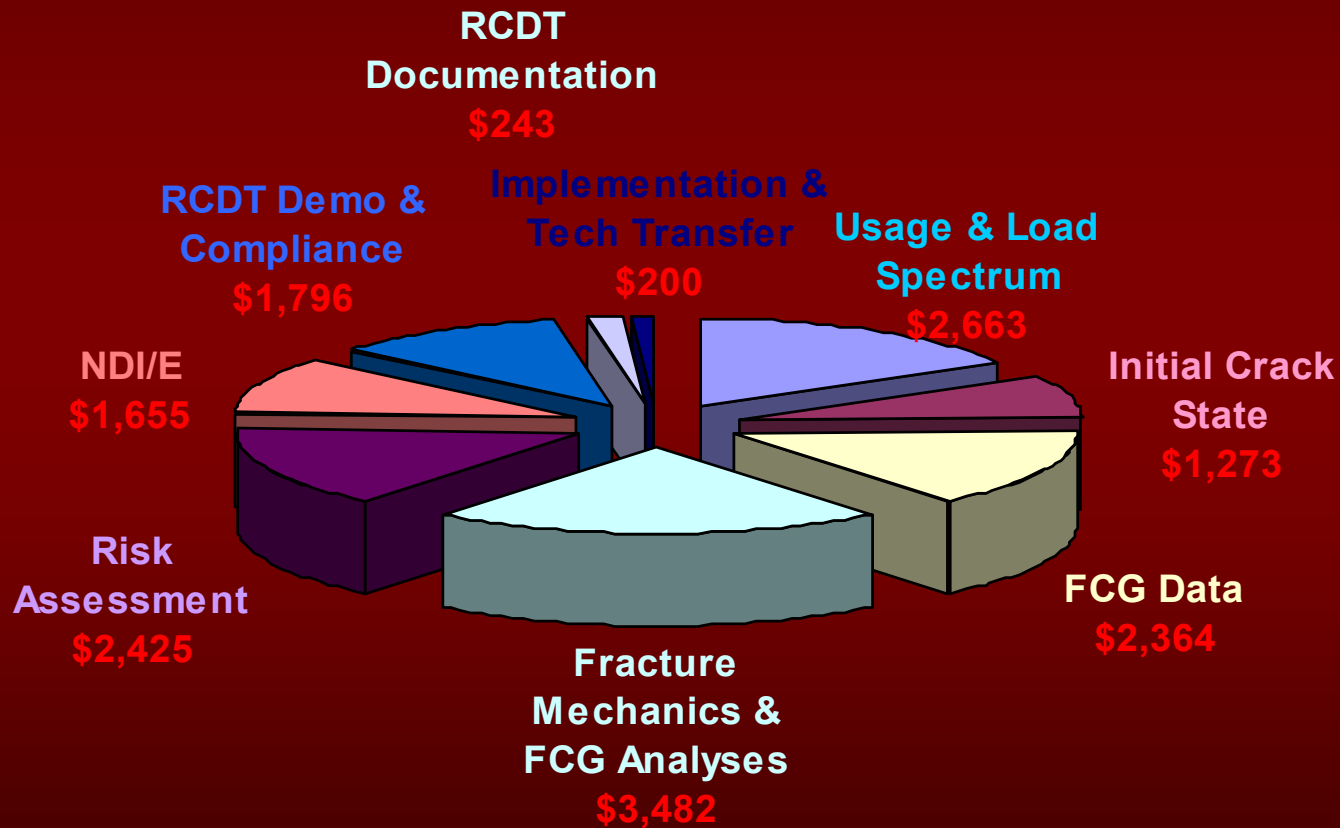
## \$16M



# FAA RCDT R&D 10-Year ROM (\$K)

## FY06 - FY15

### \$16M





Email: [Dy.Le@faa.gov](mailto:Dy.Le@faa.gov)

Phone: (609) 485-4636

Fax: (609) 485-4004



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[www.ato.faa.gov](http://www.ato.faa.gov)

<http://airportaircraftsafetyrd.tc.faa.gov>

Questions?

# **RCDT & HUMS BAA Status – As of 3/20/06**

	<b>RCDT</b>	<b>HUMS</b>
<b>Submitted WPs</b>	<b>21</b>	<b>17</b>
<b>Reviewed WPs</b>	<b>15</b>	<b>0</b>
<b>Requested for DTPs</b>	<b>3</b>	<b>0</b>
<b>Submitted DTPs</b>	<b>0</b>	<b>0</b>
<b>Reviewed DTPs</b>	<b>0</b>	<b>0</b>
<b>Accepted for Award</b>	<b>0</b>	<b>0</b>